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Effect of NUCLEAR RADIATION on Materials at CRYOGENIC TEMPERATURES

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LOCKHEED NUCLEAR PRODUCTS

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Effect of Nuclear Radiation on materials at Cryogenic Temperatures

PREPARED UNDER

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APPROVED BY

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NASA CRYOGENICS
PROJECT MANAGER

Lockheed-Georgia Company

LOCKHEED
NUCLEAR
PRODUCTS

A Division of Lockheed Aircraft Corporation

FOREWORD

This quarterly report is submitted to the Office of Space Launch Vehicles of the National Aeronautics and Space Administration in accordance with the requirements of NASA Contract NASw-114.

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1 INTRODUCTION AND SUMMARY

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This report describes the progress made during the quarter, April through June 1963, on Contract NASw-114.

Preparation for the in-pile screening test program continued with test loop and transfer system carriage assembly modification.

Remote tool fabrication continued during the period.

Data were assembled for publication of an addendum to the Pedigree Report.

Transfer system pre-neutron procedures and test specimen changing were performed by Lockheed and observed by NASA personnel. These procedures were performed with Quadrant "D" drained.

2 EQUIPMENT

2.1 BEAM PORT SHIELD

The presence of tungsten contamination in the reactor primary water was still being studied in the early part of the reporting period. However, no further indications of removal of tungsten from the beam port shield were found.

Tests on both nickel plated and bare specimens of material from which the shield was fabricated are being continued by NASA to determine conclusively if the shield is the source of the tungsten activity level in the primary water. These tests will continue during reactor cycle #3.

The 0.5 inch thick shield plug was again inserted in the shield in preparation for its use in the in-pile portion of the screening program tests.

The polyurethane seats for the beam port valve were completed by the Fabri-Valve Company of America and were installed in both the beam port and hot cave pot. The polyurethane seats do not deform under the beam port cooling water pressure as did the neoprene seats. Therefore, the life expectancy of the seats is expected to meet acceptable standards.

2.2 TEST LOOPS

The redesigned test loop head covers were fabricated, machined and installed on the test loops. Inspection of the covers, after numerous insertions in both the beam port and the hot cave port, revealed no damage to the cover surface or to the port seals.

A complete check-out of the test loops was made to determine the adequacy of the loops and that the instrumentation functions properly. Several leaks were repaired during the check-out period.

The helium seals which were designed to seal helium at the mating surface of the test loop head and test loop proper, were tested at room temperature and at 30°R. The seals, made of an 1100 series aluminum, failed to hold properly in a consistent manner. Since leakage developed in many of the nuclear instrumentation seals in the 35-60°R temperature range, an intensive search was made for materials to solve this problem. The Colonial Rubber Company responded to an inquiry and provided seals made of polyurethane. The material was molded and machined to fit the grooves in the loops. The application was successful and may be sought as a temporary fix. In the meantime, further inquiries are being made with regard to materials suitable for this application. Any results which are obtained in this period will be conveyed in subsequent reports.

Seals fabricated from 2024 annealed aluminum have also been fabricated and have been partially successful but no conclusions have yet been drawn regarding their ability to perform satisfactorily on a consistent basis. Further testing will be done in the ensuing report period. To date, the seal on the forward end of the test loop has performed with no problem.

The nuclear instrumentation seal appears to be the one which does not seal consistently. The cause for this difficulty is probable due to the geometrical configuration of the sealing surfaces. This particular seal is eccentrically located in close proximity to the I. D. of a large nominal 5" diameter seal. The ten head bolts which attach the head to the test loop are located outside this large seal. The loading force is, therefore, necessarily applied to both the small and the large seal at the location where they are adjacent to each other. This in turn causes additional deflection to the thin bulkhead in the head which is one of the sealing surfaces.

One possible explanation of the failure of the 1100 series aluminum seals is that the yield strength decreases at the temperature to which the seals have been subjected. This has been substantiated by tests performed on 1099 aluminum alloy in which the yield strength has decreased at 30°R while the tensile strength has increased (reference Quarterly Report #9, page 22). Most of the difficulty in achieving a good seal is experienced in the neighborhood of 35 to 60°R. Very little information has been available on the behaviour of this alloy at that temperature range. The 2024 annealed aluminum alloy does not possess this peculiar characteristic at cryogenic temperatures and, therefore, may be the solution to the problem even though it does have a higher yield strength.

All dynamometers were calibrated against a Moorehouse Proving Ring calibrated by the National Bureau of Standards especially for this purpose. This was accomplished by stressing the Moorehouse Ring simultaneously with the extensometer undergoing calibration in an Instron Tensile Testing Machine borrowed from NASA for this use.

All extensometers were recalibrated using a micrometer with 0.0001" graduation especially adapted for this purpose as the calibration fixture.

All stress and strain measuring and recording equipment has been checked and is in good operating condition and ready for resumption of the testing program.

2.3 REMOTE HANDLING EQUIPMENT

The test loop transfer cask is in the final fabrication phase at CPC Engineering Corporation. The voids have been filled with 200 mesh pulverized lead and the cask probed for radiation leakage. The 18" radius skirt at the bottom of the cask was inspected and the radius was found to be below acceptable standards. The vendor proceeded to build a jig and reworked the skirt toward meeting design specifications. Final acceptance of the cask is dependent on its condition and performance during checkout at Plum Brook.

Additional work has also been performed in fabricating tooling to implement remote specimen changing in the hot cave.

2.4 SAMPLE CHANGE SYSTEM

Continued failure of the drive system prompted a thorough reassessment of the stresses involved in the carriage and a redesign of the carriage assembly to provide a sure fix based on the results of the stress analysis. The upper rail is reinforced with additional stainless steel bolts to minimize deflection of the rail under load.

Since the Torrington Company, our supplier for cam followers, was closed for vacation during this critical period, the outer and inner races, the pins, shafts and cages were subcontracted and the units assembled by Lockheed. Needle bearing drawings and specifications were provided by the Torrington Company gratis.

New worms and worm gears were procured from Boston Gear. These units will be installed and "worn in" prior to in-pile testing.

Other problem areas have been investigated in the latest modification to the carriage assemblies and it is believed the units are now in condition to operate over a period of time without replacing parts.

A carriage assembly was tested using both a simulated loading system and in actual installation, it was tested in the beam port using an auxiliary pressurizing method since the reactor primary coolant pump was not operating at this time. After these tests, the carriage was disassembled and considerable damage was evident. The cam followers fabricated from 17-4 PH material had failed completely with both needles and races damaged. Several of the followers had seized and had flat spots on the outer race due to rubbing on the rails. There was also some evidence of galling on the upper rail which was deflecting. This was determined by placing dial indicators on the rail. The load also elongated the holes in the 304 SST material to which the roller assembly was attached.

The roller assemblies have been redesigned now to enable the assemblies to carry larger loads. The cam followers made from

17-4 PH material were discarded and needle type bearings have been utilized. An integral type cage is incorporated to provide a support on both the inboard and outboard sides of the bearings. The bearings are made from 440C heat treated material as recommended by the Torrington Company. The pin to attach the cage to the yoke assembly is also an integral part of the cage to further assist in obtaining a rigid structure. Bushings are being incorporated in the brackets of the yoke assemblies also to provide a hard surface which will support the bearing load without deformation. The fit between the cage and bracket is close and held to tight tolerances, again for the purpose of maintaining a rigid structure.

In addition, the upper rail has been redesigned so that it now consists of two pieces. A short removable section at the aft end will be used to eliminate the necessity of removing both of the upper rails entirely to remove or install a yoke assembly.

As a standby measure, in the event that the worm gear drive does not provide satisfactory results, a chain drive system was designed and most of the material to build the system was procured. This new system would operate with chain and sprockets mounted on the side of the carriage. This will not be used unless the worm - worm gear method fails during tests.

The Clevite hydraulic motors were returned to the vendor with the specifications "leak safe" emphasized. The motors were to be tested under full load for 10 hours prior to acceptance.

The vendor redesigned the graphitar seal and operated the motors successfully for the required length of time under load conditions with no leakage evident. The motors have undergone further tests by Lockheed and the leakage problem is apparently solved.

The hydraulic pump, also a Clevite product, was returned due to leakage but was repaired quickly and reinstalled. The vendor indicated that the seal used in the pump may not last longer than 25 operating hours. They were advised that this limitation was not acceptable and that we could not possible change seals each 25 hour operating period. As a result, a new seal was installed and an elapsed time meter is measuring the actual operating time to determine the performance of the seals.

2.5 HOT CAVE

During the period covered by this report, considerable effort was expended in the refinement of remote handling tool design and the modification of existing tools and the manufacture of new tools to facilitate the sample changing procedure and overall hot cave operation.

The exhaust equipment, including filters, was tested during this period both with the roof block in place and out of place and the air flow and differential pressure found in all cases to meet the specified requirements of the operations manual.

3 REFRIGERATION SYSTEM

The helium refrigeration system was used extensively during this period during check out of the test loop helium seals. Further training was completed and with the exception of minor items of instruction and review, the training program is complete.

The Arthur D. Little Company replaced corroded piping with stainless steel pipe during this period. The transfer lines developed leaks and preliminary arrangements were made to return the lines to Vacuum Barrier for repair. This matter will not be closed until the next quarter.

The refrigeration system is functioning properly, otherwise, and is ready for in-pile testing.

4 TESTING

4.1 MATERIAL SELECTION FOR SCREENING PURPOSES

The final material has been selected by NASA for the out-of-pile and in-pile screening tests. The material selected is an austinetic manganese alloy steel which contains approximately 18% Mn as primary austenizing agent and small percentages of Cr, Cu, Ni and N_2 to provide low temperature stability of austenite. This particular alloy, designated T-450 by Union Carbide Corporation, has been sugjected to low temperature tests by their Linde Division in Tonawanda, New York. The results of these tests contained in their report, "The Low Temperature Mechanical Properties of Some Austinetic Manganese Steels", F. S. Death and H. M. Long, indicate that this is a favorable alloy for inclusion in this program.

The complete list of materials approved for inclusion in the screening program is as follows:

Aluminum Alloys

Aluminum 1099	H-14
Aluminum 2014	T-651
Aluminum 2024	T-351
Aluminum 2219	T-87
Aluminum 5083	H-321
Aluminum 5086	H-32
Aluminum 5456	H-321
Aluminum 6061	T-6
Aluminum 7079	T-6
Aluminum 7178	T-651
Aluminum X-250	T-4
Aluminum A-356	T-6
Aluminum B-750	T-5

Nickel Alloys

Rene' 41	Solution Treated

K Monel	Cold Drawn, Annealed, Aged
Inconel	Cold Drawn
Inconel X	Solution Treated, Aged

Steel and Stainless Steel Alloys

Stainless Steel AISI Type 304	Annealed
Stainless Steel AISI Type 310	Annealed
Stainless Steel AISI Type 347	Annealed
Stainless Steel Type AM-350	SCT
Stainless Steel AISI Type 440C	Quenched and Drawn, Rc^{58}
Stainless Steel Type 17-7 PH	RA-950
Super Alloy A-286 (AMS 5735)	Solution Treated, Aged
Super Alloy A-286 (AMS 5737)	Solution Treated, Aged
Nickel Alloy Steel ASTM A-353	Normalized
Austenitic Manganese, 18% Mn, "Union Carbide designation, T-450"	Annealed

Titanium Alloys

Titanium 55A	Annealed
Titanium 5 Al-2.5 Sn	Annealed
Titanium 5 Al-2.5 Sn (Extra Low Interstitial)	Annealed
Titanium 6 Al-4V	Annealed
Titanium 6 Al-4V	Solution Treated, Aged
Titanium 8 Al-1 Mo-1V	Annealed

4.2 REVISION TO MANUALS

The Experiment Design and Hazards Analysis Manual and the Experiment Operations Manual were reviewed by both NASA and Lockheed personnel. Changes were made to both manuals to reflect the current design and operating status of the experiment.

In addition, procedures and check lists outlining the operating of the refrigeration system and transfer system were prepared and submitted to NASA for review and approval. These procedures and check lists were approved and published for use in the experiment. Maintenance and monitoring procedures were also prepared and edited and published after approval by NASA.

The Lockheed experiment to learn the effects of radiation on materials at cryogenic temperatures has been approved for in-pile testing insofar as safeguards is concerned.

4.3 PRE-NEUTRON TEST PROCEDURES

Pre-neutron procedures were completed on the transfer system and test loops during this reporting period with the quadrant in which the testing will be performed in a dry condition. During these tests, only two test loop carriages and test loops were involved. The refrigeration lines and instrumentation lines were installed on the systems and they were operated in various configurations in the transfer system to ascertain if there were any inteference problems involved. An auxiliary method of pressurizing the beam port in lieu of using the reactor primary coolant water pumps was used during this test operation. Operation in both the beam port and the hot cave port was satisfactory. It has been determined though that additional assistance will be necessary to assist in maintaining the instrumentation and service lines in an orderly condition. This has been in the original plan, however; therefore, it is not an additional requirement.

A test specimen change was also accomplished with a test loop in the hot cave and using remote handling techniques.

These procedures have been witnessed by NASA technical personnel.

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